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METHOD AND DEVICE FOR AUTOMATICALLY DETERMINING PERMEABILITY OF
AN OBJECT MADE OF POROUS MATERIAL WITH SEVERAL ALTERNATING
POROSITY LEVELS
[PROCEDE ET DISPOSITIF POUR LA DETERMINATION AUTOMATIQUE DE LA
PERMEABILITY D'UN OBJET EN MATIERE POREUSE A PLUSIEURS NIVEAUX DE
POROSITE ALTERNES]

G. Cholet

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INVENTOR(S)	(72):	G. Cholet
APPLICANT(S)	(71):	Societe Nationale d'Exploitation industrielle des tabacs et allumettes
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TITLE	(54):	Method and device for automatically determining permeability of an object made of porous material with several alternating porosity levels
FOREIGN TITLE	[54A]:	Procede et dispositif pour la determination automatique de la permeabilite d'un objet en matiere poreuse a plusieurs niveaux de

Method and device for automatically determining permeability of
an object made of porous material with several alternating
porosity levels

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The present invention concerns a method and device for automatically determining the permeability of an object made of porous material with several alternating porosity levels, this object capable of being present in the form of a sheet or band of porous material that includes successive areas that have in alternating manner, according to a pre-established periodicity, different levels of permeability.

It pertains in particular but not exclusively to inspection and measurement of the permeability of areas of a strip of paper of the kind described in the patent EP 0486213 A1 with filling of cellulose fiber that has a succession of transverse areas of different volumetric mass and therefore of different permeability. This strip of paper can be used for example, but not necessarily, to make self-extinguishable cigarettes.

In a general way it is known that the measurement of permeability of a sheet of porous material is taken by means of a

¹ Numbers in the margin indicate pagination in the foreign text.

permeameter that includes a measurement head that includes two tubular parts that can move with respect to one another, in such a way as to be able to come to a stop against one another, thereby capturing the sheet, at least partially and in airtight manner, and thereby delimiting two coaxial chambers that open onto two distinct sides respectively of the sheet. One of these chambers is connected to a measurement circuit that includes a flow meter, some means of pumping capable of causing in the measurement circuit a pressure or a void and some regulating means capable of maintaining a certain pressure in the measurement circuit. /2

It turns out that the manufacturers of the aforementioned kind of porous material strips, just as the users of these strips, want to be able to monitor the permeability of the porous areas of the strip by taking a measurement in the middle of each strip, whether it is an area of low permeability or an area of high permeability.

In order to achieve these results one must satisfy the following two conditions:

- Use of a measurement head in which the chambers have dimensions less than those of the areas such that when the two chambers are centered on one area, the measurement pertains only to the permeability of a central zone of this area;

- The implementation of the means (method and device) that allow one to center the measurement head on each of the areas of which one wishes to measure the permeability.

The first condition is easily satisfied if one knows the dimensions of the areas (in principle furnished by the paper manufacturers).

In contrast, the second condition presents a real problem because the porous areas of the strips are not visible and therefore it is not possible to initialize the position of the strip by a visual reference point.

The invention therefore more particularly has as another goal a method of permeability determination that effectively solves this problem and does so completely automatically. /3

For this purpose, it starts from the premise that it is possible to make the permeability profile of the strip coincide with a sinusoid (obtained by sinusoidal regression starting from this profile) of which the extrema determine the position of the area environments in question.

Consequently, the method according to the invention includes:

- On one hand, a preliminary phase that includes determination of the permeability of the strip on at least one width of period T that includes two

;successive areas, the determination of a sinusoid by sinusoidal regression starting from the resulting profile, determination of the position of the two extrema of this sinusoid and centering of the measurement head on the second extremum, and;

- On the other hand, a measurement phase that includes step by step advance of the paper strip by steps of $T/2$, and for each step a permeability measurement.

Determination of the permeability profile taken in the preliminary phase could be carried out by executing a succession of permeability measurements based on a period t that is much less than the period T (millimetric for example).

The sinusoidal regression carried out in this phase could be accomplished by the method of least squared, starting from the values obtained during determination of the permeability profile.

Of course, the invention also concerns a device for implementing this method.

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One mode of execution of the invention will be described subsequently in a non-limiting example with reference to the attached drawings in which:

Figure 1 is a top view of a strip of paper that has in succession some areas of low permeability and some areas of high permeability;

Figure 2 is a diagram that shows the permeability profile of the strip for a period of time T;

Figure 3 is a diagrammatic sectional view of a device for automatic permeability determination of a strip of paper of the kind shown in figure 1;

Figure 4 is a diagram that indicates the permeability measurement points obtained during the permeability profile determination phase and the corresponding regression curve.

In the example shown in figure 1 the strip of paper 1 is cigarette paper that includes two alternating series of areas P1, P2 that have two different permeabilities in order to allow self-extinguishing of discarded cigarettes.

The areas P1, P2 extend perpendicularly to the longitudinal axis OX of the strip 1. The area of low permeability P1 has a width less than that of the area of high permeability P2. This strip can be made in conformity with the manufacturing method described in the aforementioned patent EP 0,486,213 A1. /5

As mentioned previously the successive areas P1, P2 of the strip are not distinguishable visually (the separation lines indicated in figure 1 are not present physically). Consequently the only possibility of referencing the strips is to take a point to point measurement (millimeter by millimeter for example) of the permeability of the strip along the longitudinal axis OX of the latter, in order to obtain a permeability profile PP like the

one indicated in figure 2. This profile has a toothed shape that includes lower levels P'1 that correspond to the areas of low permeability P1 and upper levels P'2 that correspond to areas of high permeability P2. These levels P'1, P'2 are connected to one another by slopes that correspond to the transition zones between the successive areas P1, P2.

It is clear that the determination of the middle M of the levels P'1, P'2 of the resulting profile allows one to obtain the position of the transverse median axes AT of the areas P1, P2.

As shown in figure 3 the automatic permeability determining device of the strip of paper 1 includes a measurement head 2 that includes two tubular parts 3, 4 approximately of the same size, between which the strip 1 passes. These two tubular parts 3, 4 are movable with respect to one another and can be placed coaxially vis-à-vis the other to come to a stop against one another as they compress the strip 1 between their edges B, B'. Advantageously, the edges B, B' could be covered by a lining that allows one to guarantee good air-tightness between the two parts, 3, 4 of the head 2 and the strip of paper 1.

The tubular part 4 is open at its two ends while the tubular part 3 includes a bottom F, located on the side opposite the edge B' in such a way as to constitute a suction chamber enclosed by the strip 1.

This chamber is connected to the suction passage 5 of a traditional permeameter 6, of the kind that is described in the patent FR 2,779,882 filed in the name of the applicant for example. /6

In this example, the edges B, B' of the two parts of the head delimit, as shown in figure 1, the shape of a rectangular slot FR whose width is much less than the width of an area P1, P2 while the length remains less than the width of the strip 1.

The strip 1, usually coming from a roll, is guided on both sides of the measurement head 2 by two respective guide roller systems, that is a system of motorized rollers 7 driven by a step motor 8 and a system of rollers 9 that allow one to ensure guidance and tensioning of the portion of the strip 1 that passes between the two parts 3, 4 of the measurement head 2.

The step motor 8 is designed so as to be able to function in two different modes, which are:

- A first mode according to which each step causes one millimeter advance of the strip 1;
- A second mode according to which each step causes an advance of the strip 1 equal to $1/2$ the sum of the width of an area of high permeability P2 and of an area of low permeability P1 (period $T/2$).

Control of this step motor 8 like control of the permeameter 6 and of the measurement head 2 are assured by a processor housed

in the permeameter 6 casing. Advantageously, this processor could be connected to various peripheral devices such as a display 10, printer 11 and a disk reader or CD ROM 12.

Of course, this processor must be programmed so as to be able to achieve sinusoidal regression and to determine the extrema of a sinusoid (values for which the derivative is cancelled out and symbols of the second derivative for these values). /7

In conformity with the method according to the invention, before carrying out measurement of the permeability of the successive areas of the strip, the device must execute a preliminary phase of adjustment that includes the following stages:

- A stage that includes a millimeter by millimeter permeability measurement over a length of strip equal to at least the sum of one width of area of low permeability and of a width of area of high permeability (period T). (The measurement points are indicated by diamond shapes on the diagram shown in figure 4).

For this purpose the step motor 8 is switched to its first mode of functioning (millimeter advance). During this stage the measured values of permeability,

associated with information relative to the position of the strip 1 are stored in the processor memory.

- A second stage in which the processor determines a sinusoidal curve CS in coincidence with the values picked up during the first stage.
- A third stage in which the processor determines the abscissas of the two extrema of the sinusoid CS obtained in this way, which correspond to the transverse median axes AT of two successive areas P1, P2 of the strip 1.
- A fourth stage in which the processor determines the deviation between the abscissa of the second extremum and the axis OO' of the measurement head 2 and controls displacement of the strip 1 so that it can place the said abscissa and the said axis OO' in coincidence and thus obtain the desired adjustment. /8

Once this preliminary stage is accomplished the device starts the measurement phase. For this purpose the step motor 8 is switched to its second functioning mode (period $T/2$).

At each step the measurement head 2 is found to the right of the transverse median axis AT of one area P1 or P2 and the permeameter measures the permeability. The result of this measurement is then stored in memory with the data pertaining to the position of strip 1.

This information could then be visualized on the display and/or printed by the printer in order to be able to carry out inspections.

As mentioned previously, determination of the sinusoid CS is obtained by means of a regression calculation that allows one to obtain a sinusoidal curve having the equation:

$$Y = A_0 + A_1 X \cos(2\pi X/T) + B_1 \sin(2\pi X/T)$$

a formula in which

A_0 , A_1 and B_1 are the coefficients to be determined

X is the abscissa (which expresses a length varying from 0 to T)

Y is the ordinate (which expresses a permeability).

The determination of the coefficients A_0 , A_1 and B_1 are then obtained with the help of the following expressions:

$$A_0 = (\sum Y_i) / T$$

$$A_1 = 2(\sum (Y_i \cos(2\pi X_i/T))) / T$$

$$B_1 = 2(\sum (Y_i \sin(2\pi X_i/T))) / T \quad \quad \quad \underline{/9}$$

Expressions in which:

i is an index that varies from 1 to T

x_i and y_i are values of x and y for a certain value of i .

From these expressions it is possible to deduct the following relationships:

$$\text{if } A_1 = 0 \quad \text{then } X = T/4 \text{ if not } X = (T \arctan(B_1/A_1)) / (2\pi)$$

$$\text{if } X < 0 \quad X = X + T/2$$

if $B1 > 0$ X corresponds to a maximum (high permeability)

if $B1 < 0$ X corresponds to a minimum (low permeability).

Of course, the invention is not limited to this method of calculation, it being understood that many solutions are also likely to arrive at similar results. /10

CLAIMS

1. Method for automatic permeability determination of a sheet or of a strip (1) of porous material that includes some successive areas (p1, P2) that have in alternating manner, and according to a pre-established period T, some levels of different permeability, this method involving use of a permeameter that includes a measurement head (2) vis-à-vis which the said sheet or the said strip (1) can be displaced step by step, characterized in that it includes:

- A preliminary phase of adjustment that includes the determination of the permeability profile of the sheet or of the strip over the length of a width that corresponds to at least one period T that includes two successive areas, determination of a sinusoid (CS) from the resulting profile, determination of the position of the two extrema of this sinusoid and centering of the measurement head (2) on the second extremum, and;
- A measurement phase that includes, after centering of the head, step by step advance of the sheet or the

strip (1) by steps of $T/2$, with a permeability measurement made at each step.

2. Method according to claim 1 characterized in that the determination of the permeability profile is obtained by carrying out a succession of permeability measurements based on a period t the is much less than the period T .

3. Method according to one of the preceding claims characterized in that the determination of the said sinusoid (CS) is made by a regression calculation, starting from the values obtained during the determination of the permeability profile.

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4. Method according to claim 3 characterized in that the said regression is obtained by the method of least squares.

5. Method according to one of the preceding claims characterized in that the said strip (1) consists of cigarette paper that includes two alternating series of areas (P1, P2) that have two different permeabilities, these areas extending perpendicular to the longitudinal axis of the strip (OX).

6. Device for the implementation of the method according to one of the preceding claims, characterized in that it includes a measurement head (2) made of two tubular parts (3, 4) between which the said strip (1) passes, these two parts (3,4) being movable with respect to one another in order to be able to tighten the strip (1) between their edges (B), the strip capable

of being displaced by means of a step motor (8) designed so that it can function in two modes, a first mode with millimeter steps in which the step corresponds to $1/2$ the sum of the widths of two consecutive areas (P1, P2).

7. Device according to claim 6 characterized in that control of the step motor (8) and control of the movements of the measurement head (2) are assured by a programmable processor so as to calculate the said sinusoid (CS) as well as the extrema of this sinusoid (CS).

Four figures.

Figure 1. low permeability; suction nozzle; high permeability.

Figure 2: permeability.

Figure 4: permeability; measurements; regression.

FIG.1

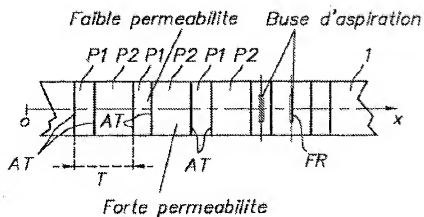


FIG.2

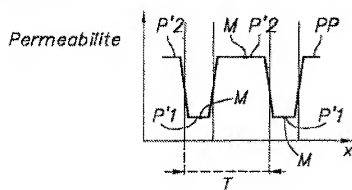


FIG.4

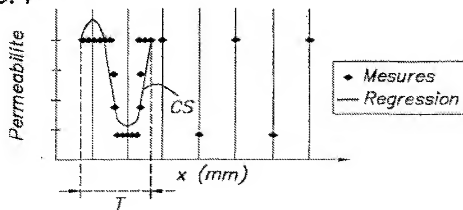


FIG. 3

